195-24.

Quick Hardening Concrete

A Practical consideration
of products, methods,
results and
costs

North American Cement Corporation
HAGERSTOWN - - - MARYLAND

[BLANK PAGE]

QUICK HARDENING CONCRETE

TABLE OF CONTENTS

[BLANK PAGE]

INTERNATIONAL

THE constant development of new products and new methods in concreting, the constantly broadening use of Portland cement in every type of construction, the increasing variety of special conditions which it is called upon to meet, and the growing pressure for speed, have led us to prepare this brief consideration of the most economical and effective methods of handling concrete work in which early set and early strength are of importance.

In recommending the use of our particular product, Cal, to meet certain requirements of modern concreting, we have carefully limited ourselves to those uses which the tests of experts and the experience of thoroughly capable and practical men have amply demonstrated.

The properties of Cal which are here *generally* discussed may readily be applied by the reader to his individual problems of road and street building, reinforced concrete construction, stucco, brick mortar,* concrete products.

Our technical staff will be very glad to consult with anyone interested in any phase of the concreting problems discussed in this booklet.

**The effect of Cal on mortar for use in brick construction, is in general, the same as outlined in the following pages for concrete. It is important to note, in this connection, however, that five years of job experience have confirmed the finding of the U. S. Bureau of Standards (see Technological Paper No. 174, page 12) that the addition of Cal to brick mortar does not cause efflorescence.*

Fundamental Requirements for Good Concrete Work

IN the making of the best Concrete and Mortar, there is no substitute for the selection of proper materials and insistence upon good workmanship.*

Materials:

1. Clean sand and stone.
2. Well graded aggregates.
3. Mixing water that is *fit to drink.*

Mixing:

1. The least amount of gauging water should be used that will give the workability necessary for the job. Keep reducing the amount of water until you find the point where the mixture is too stiff to work, and then add a little bit extra, (a pint often makes the difference in a 1-bag batch) until it can be handled easily.

2. Long mixing. Mix concrete for *at least* one minute and mortar for at least two minutes.

**Valuable facts have been gathered by the Portland Cement Association on these points, and are fully given in its pamphlet entitled "Concrete Data for Engineers and Architects." Copies can be obtained free by application to any one of the numerous district offices of the Association, or to the headquarters at Chicago, Ill.*

Protection:

1. Protection from freezing. (See pp. 15-16).

2. Protection from hot sun or drying winds. Just as soon as the concrete or mortar is placed, protect the exposed surfaces from the warm sun and from wind and other air currents, wherever job conditions make this possible, and continue the protection for several days.

Acceleration: Possible—Practical—Economical

THE modern need for accelerating the hardening of Portland Cement mixtures is well presented in the following statement from Technologic Paper No. 174 of the U. S. Bureau of Standards:*

"A demand for a practical and efficient material for accelerating the hardening of Portland cement mixtures has received considerable attention in recent years. The need for such a material becomes of more consequence with the introduction of more rapid methods in construction and with the increasing amount of concrete repair and replacement work. Serious problems arise when it becomes necessary to interrupt or divert traffic for the duration of time required for concrete to harden sufficiently. The increased cost of lumber for forms has necessitated a more judicious use of such material, and its removal for further use as soon as the strength of the concrete will allow. This applies even more to the use of steel forms, which are rapidly replacing wooden forms in a great many types of concrete construction.

"Considerable work toward the development of an accelerator for concrete has been done by the U. S. Bureau of Standards, which found that calcium chloride was the most effective of the various substances tested."

The rate of acceleration to be obtained with calcium chloride is well know, and is generally accepted as adequate in all jobs except those which absolutely require a highly exceptional rate. However, as the paper above quoted goes on to say: " . . . . the use of commercial calcium chloride in concrete is attended by difficulties caused by its highly hygroscopic property and by the handling of the solution."

One of these difficulties is that calcium chloride is added in proportion to the volume of gauging water, which may vary from 25 to 45 gallons per cubic yard of a 1:2:4 mix, according to the dryness or wetness of the aggregates used, and without any relation to the amount of *cement* which the calcium chloride is intended to harden. The proportion is, therefore, extremely variable and the results necessarily uncertain. Too low a percentage of calcium chloride reduces the rate of hardening—too high a percentage may give "flash set" and seriously affect the ultimate strength of the concrete.

The *second* difficulty in using free calcium chloride is that, when it has been added to a barrel of gauging water, it disappears and leaves no trace which the man at the mixer can recognize. This invites the danger of a double dose, or no dose at all.

The *third* difficulty is that free calcium chloride is highly electrolytic and is, therefore, not advisable for use between or near electric railway tracks—where it may corrode the rails and also develop checks and cracks in the concrete from the electrolytic action.

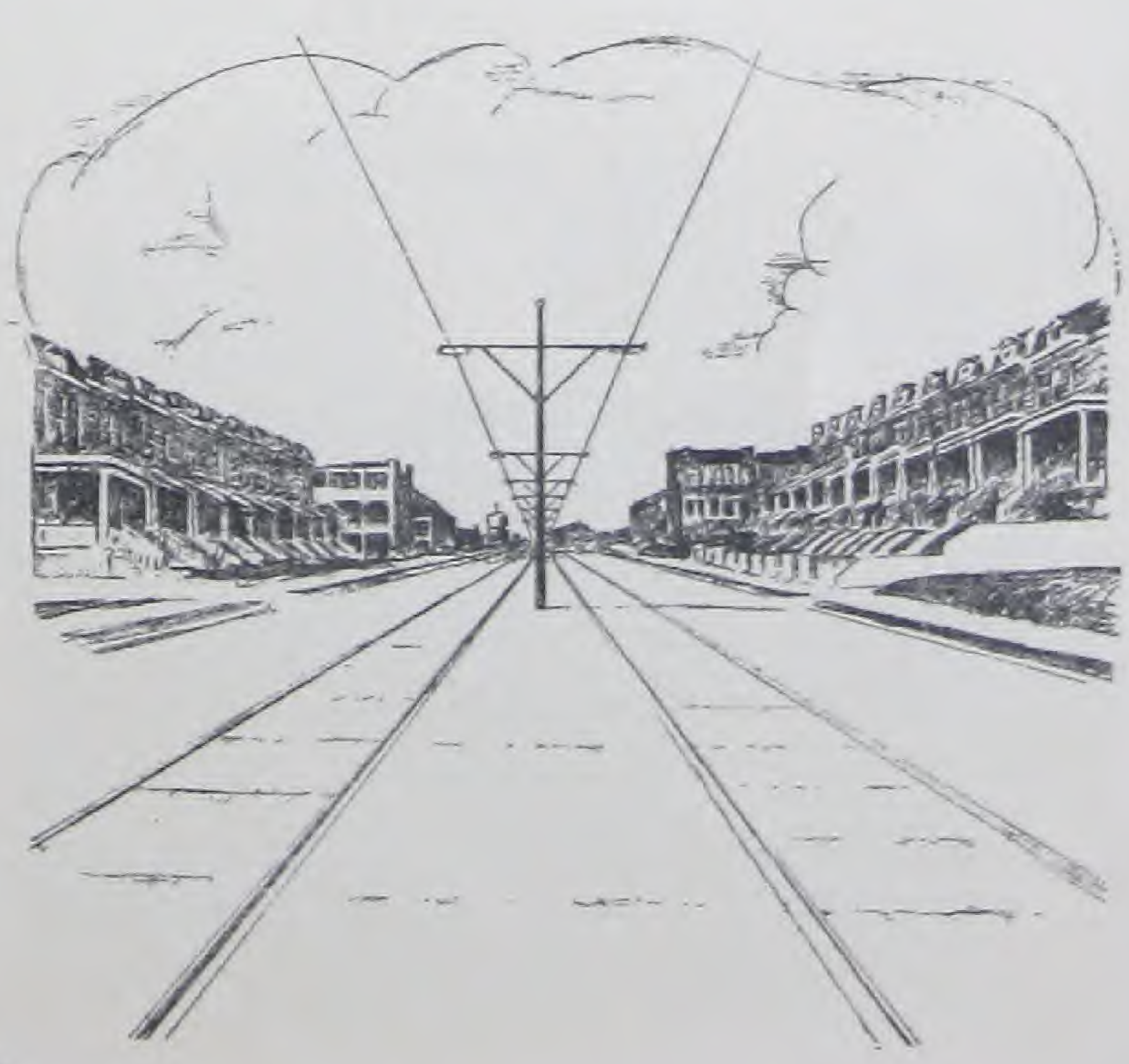
Chiefly as a means of making acceleration a safe, practical and economical operation *under the conditions of average construction work,* and with the grade of labor ordinarily employed, our chemical staff developed a compound which uses calcium chloride as a base, yet eliminates to a large degree the amount of labor and the chances of error involved in mixing.

This compound, Cal, is a dry white powder which requires no solutions or extra preparations, but is added directly to the cement and aggregates, *at the mixer.*

In the form of Cal, the corrosive properties of calcium chloride are entirely neutralized. Cal alone is actually an inhibitor of corrosion.

Regarding the accelerative value of Cal, we quote again from U. S. Bureau of Standards Technological Paper No. 174 (page 7):

"The effect of Cal on the setting time of normal Portland cements may be seen by examing the results given below. The set was hastened in all cases and to a greater extent by the larger percentage of Cal."



Cement	Ratio (percentage) Cal to cement	Ratio (percentage) water to total mixture	Initial set		Final set	
Sample Nos.:			H.	M.	H.	M.
1	None	23.4	4	0	8	10
	5	21.9	2	15	5	45
	8	21.0	1	50	5	30
2	None	23.2	3	35	6	45
	5	21.7	1	50	4	10
	8	20.8	1	25	3	30
3	None	23.4	3	40	7	0
	5	21.9	2	45	5	45
	8	21.0	2	5	4	25
4	None	24.0	4	40	7	30
	5	22.5	3	0	5	40
	8	21.6	1	50	3	40
5	None	22.5	3	35	6	25
	5	21.0	1	55	2	55
	8	20.1	1	5	1	55

From Technologic Paper 174, U. S. Bureau of Standards.

The official conclusion drawn from the tests here tabulated, are given on page 22 of the above paper.

"The setting of normal Portland cement mixtures may be hastened by Cal to an extent which is very desirable in concrete construction requiring a finished surface. The finishing operation may proceed with much less delay after the concrete has been placed, which should result in cutting down overtime labor. This hastening of the set is

not objectionable in any type of construction providing the concrete is placed soon after it is gauged with water.

"Cal was used in a concrete floor topping alongside of topping containing no accelerator, for the purpose of observing the effect under actual field conditions. The treated topping was ready for the finishing operation in about one-half the time required by the untreated, as judged by the finisher. This agreed very closely with the results of the laboratory tests on the rate of setting of the two mixes by means of the flow table."

If the calcium chloride could be eliminated from Cal without reducing the effect on fatness and workability, and if full advantage were taken of the drier mix which this workability allows, a very considerable degree of acceleration would still be achieved.

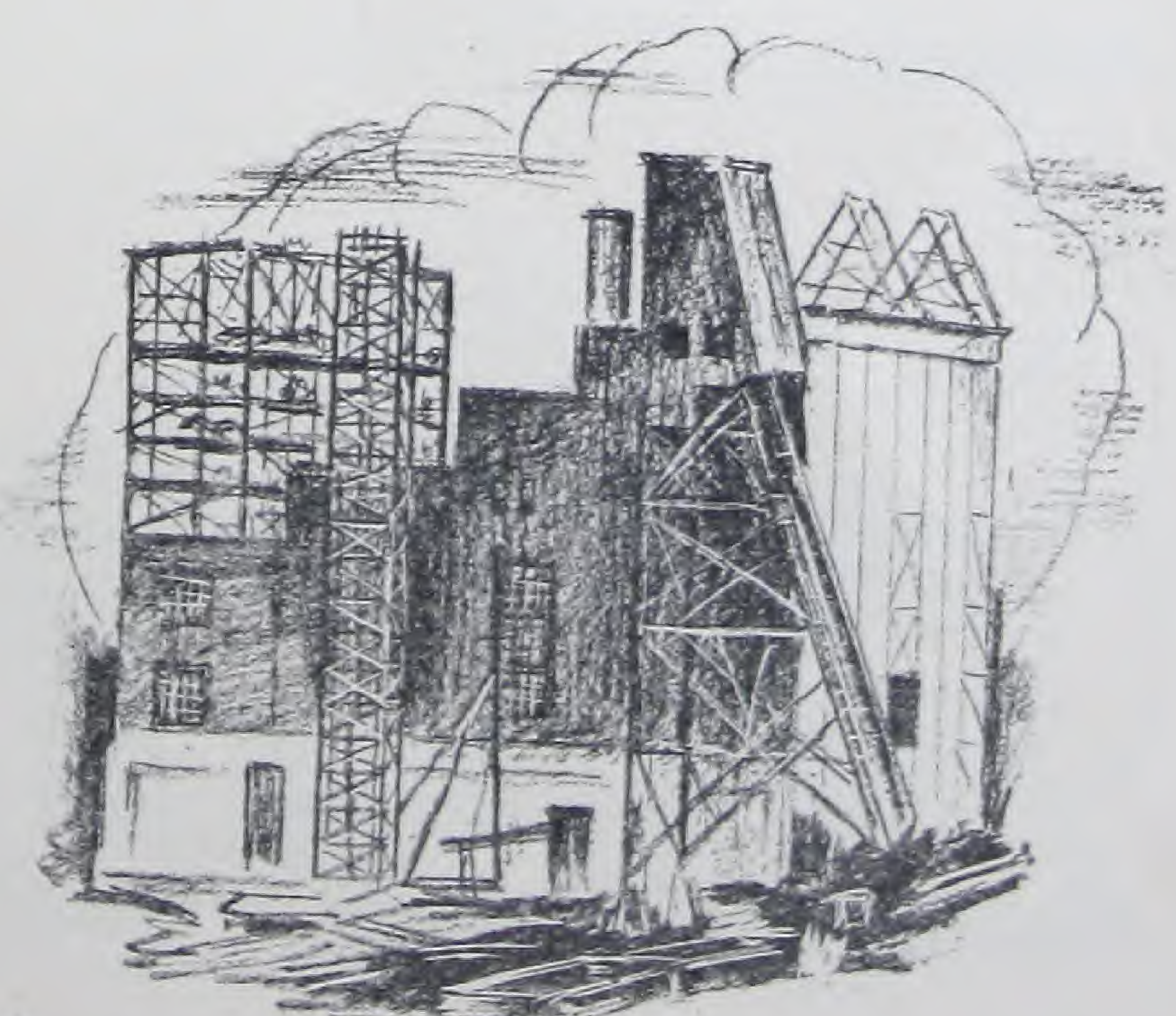
In the case of Cal, there is actually a *double* acceleration:

1. That produced by its calcium chloride content.
2. That produced by the lower water ratio which its fattening effect makes possible.

Effect of Accelerators on the Strength of Concrete

WHETHER calcium chloride alone, or calcium chloride in the form of the Cal compound, be used, it has been established that a rapid increase of strength may be looked for.

The conclusions with regard to the operation of Cal are summarized in the following quotation from pages 22 and 24 of the U. S. Bureau of Standards Technologic Paper No. 174.



"All Portland cement mixtures treated with Cal attained greater strength at the 2-day and 7-day periods than the corresponding untreated mixtures. The percentage increase in the strength of mortar at the 2-day period obtained by an addition of 5 per cent Cal to cement ranged from 40 to 140. The strength of the treated mortar at two days was equal to the strength of the untreated mortar at three and one-half to eight days. These calculations are made from the results of tests in which the test pieces were stored in water, damp sand, or damp closet.

"Treated mortars stored in the laboratory air attained at 2 days strength greater than that of the untreated mortars at 28 days. This was due to the rapid drying out of the small test pieces and the comparatively slow rate of gain in strength after the 2-day period. However, this indicates that Cal is especially advantageous in cement mixtures which are necessarily subjected to any drying-out action.

"The increase in strength produced by 5 per cent Cal in concrete mixtures at the 2-day period ranged from 52 to 135 per cent, and the strength of the treated concrete at the 2-day period was equal to that of the untreated at from three to four and one-half days. On an average this represents a saving of approximately one-half the time in operations which are dependent upon the strength of the concrete at early periods. The effect of the air storage in the concrete tests was lessened in degree, owing to the high relative humidity which existed throughout the storage period.

"It should be remembered that the increase in strength resulting from an addition of 5 per cent Cal does not represent the maximum which may be obtained except in very

rich mixes. As much as 15 per cent Cal was used in mortar tests, giving an increase of 220 per cent at the 2-day period."

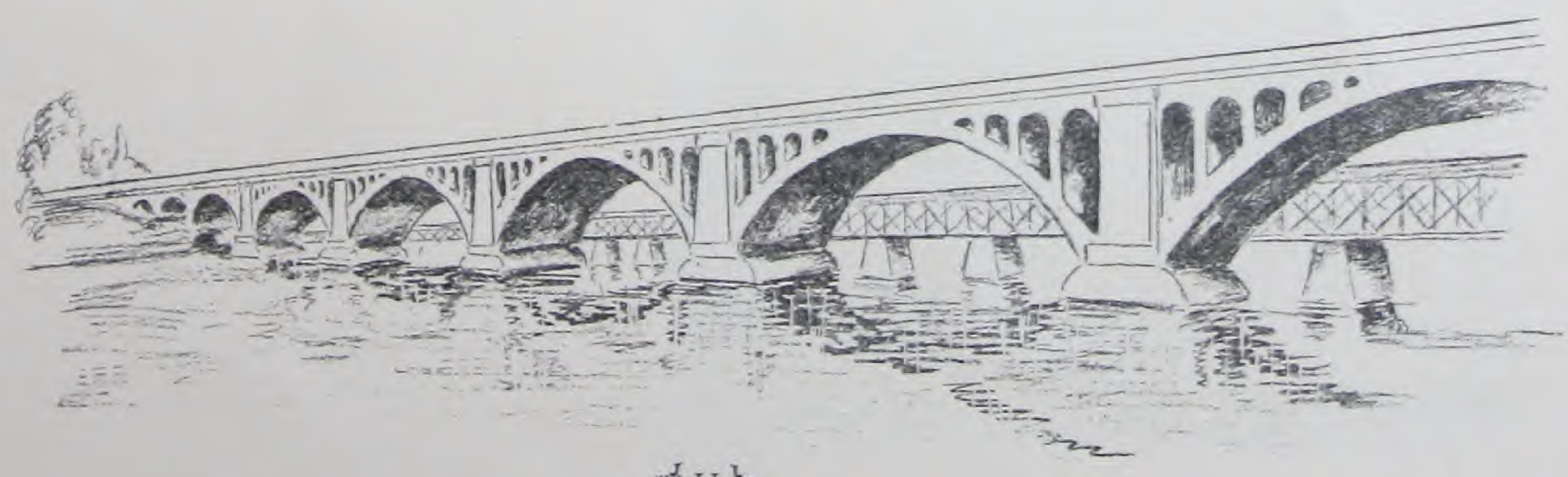
Effect of Curing on the Strength of Concrete

THE importance of controlling the conditions of curing concrete after it has been placed should not be overlooked. It has been well established that a moist atmosphere at 70° F. presents the ideal curing condition for practically all types of concrete construction, and that the maintenance of this condition gives maximum strength, durability and density to the finished structure. Such ideal curing conditions, of course, can rarely be obtained on the actual job. Variations in temperature and in humidity may extend over wide ranges, and unless special precautions are used, the resulting concrete will be equally variable.

The most severe condition which can be met in ordinary construction work during the curing period is produced by very hot and very dry weather. In such weather concrete is dried out rapidly from the surface, so that there is not enough moisture left to properly combine with the cement. The result is a soft-cured, porous and cracked surface, which offers easy entrance to rain, frost and other destructive agents of the atmosphere.

Where Cal is used with concrete cured under such drying-out conditions as are described above, the results are particularly interesting and encouraging. They are summarized as follows in the U. S. Bureau of Standards Technological Paper No. 174 Page 10):

> *"The effect of Cal under the conditions of these tests is remarkable. The strength of the treated mortar at 2 days is considerably above that of the untreated mortar at 28 days."*



The action of Cal under these drying-out conditions seems to be two-fold:

1. It accelerates the set and strengthening of the concrete or mortar so that the period in which serious drying-out is possible is reduced to the minimum.

2. Cal has the property of retaining the water of the mix and resisting evaporation.

For all work in which surfaces are necessarily exposed to sun and wind, this property of Cal will be found of real value.

Effect of Water Ratio on the Strength of Concrete

THROUGH the long and careful investigations of the Portland Cement Association, it has been demonstrated that the strength and durability of a finished concrete job depends in a very considerable degree upon the percentage of water used in the original mix. The official report of this Association makes the following statements:

"Excess mixing water weakens concrete. Sloppy mixtures sacrifice strength. One pint more water than necessary in a one-bag batch decreases the strength and resistance to wear of concrete as much as if two or three pounds of cement were left out. Concrete hardens because of chemical reactions between Portland cement and water. The quantity of mixing water is just as important as the quantity of cement.

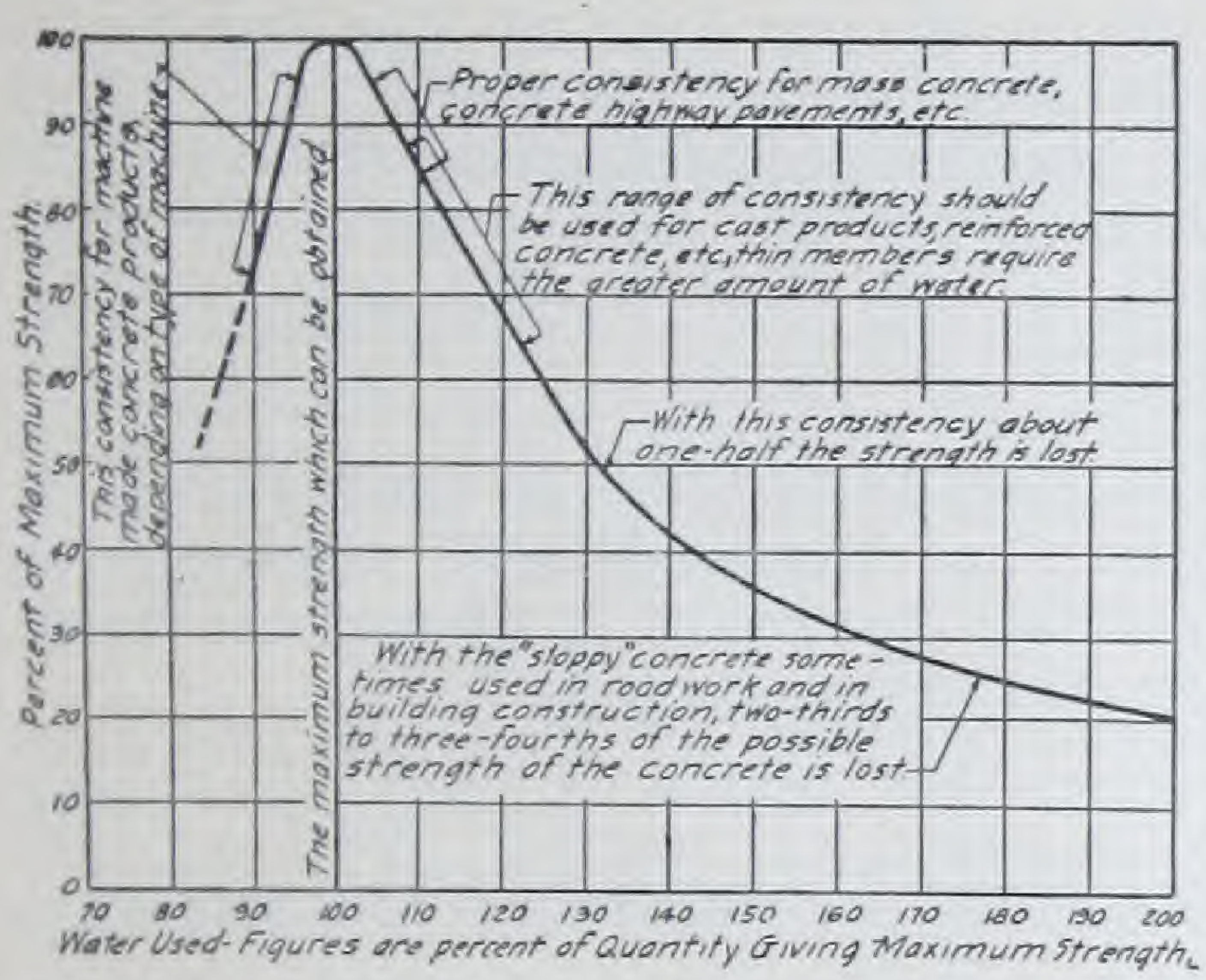


Fig. 1. Effect of Quantity of Mixing Water on the Compressive Strength of Concrete. Note: In general construction, the maximum strength can rarely be obtained, but it is possible to obtain 70 to 90 per cent of the maximum strength without additional expense by restricting the quantity of mixing water.

"The strength of concrete depends on the ratio between the volume of mixing water and the volume of cement ($\frac{W}{C}$). As long as the mixture is workable, the smaller the water-cement ratio, the stronger the concrete. Thus decreasing the quantity of mixing water and increasing the quantity of cement both add to the strength of concrete. With given proportions, the quantity of mixing water should obviously be reduced as far as possible and still obtain a plastic mixture.

"The curve in Fig. 1 shows the effect of the quantity of mixing water on the strength of concrete. It is an average of the results obtained with many mixtures and aggregates. The data on which it is based were secured from several thousand tests at the Structural Materials Research Laboratory, Lewis Institute, Chicago, Ill. Mixtures on the right of the maximum strength line were plastic; mixtures on the left were not.

"In general construction work, maximum strength can seldom be secured, because the mixture would be too stiff

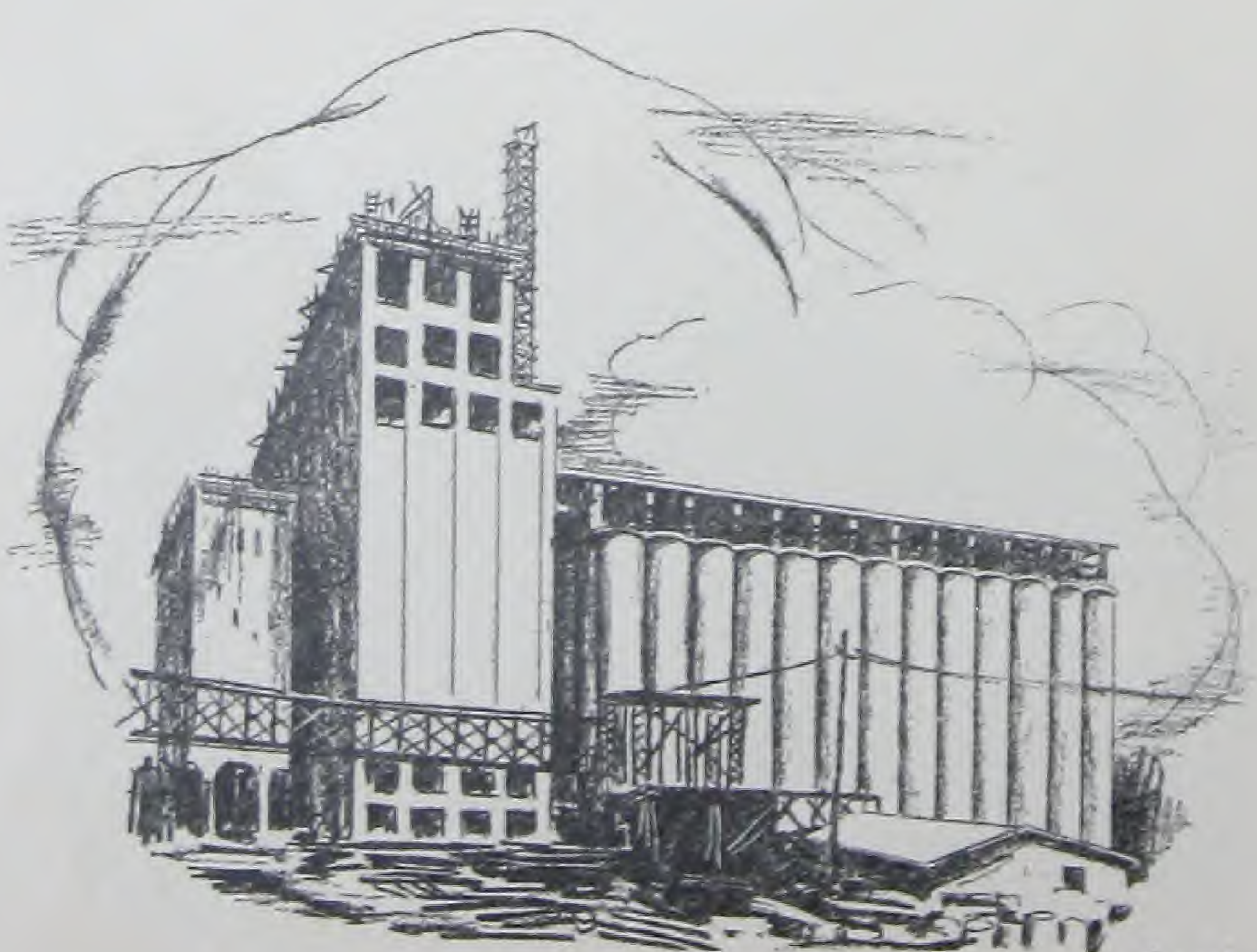
to be workable, but 70 to 90 per cent of the maximum strength can readily be obtained. This would be a great increase over the usual results, since much of the concrete placed today contains 50 to 100 per cent more water than necessary and thus attains only half or even only a quarter of its possible strength.

"Resistance to wear, which is vital in concrete pavements, floors and sidewalks, increases with compressive strength. Thus, the smaller the quantity of mixing water the more wear-resistant will be the concrete."

Reducing the Water Ratio Through the Use of Cal

As an aid to reducing the water content, Cal will be found efficient. One of its ingredients is a specially precipitated hydrated lime which acts as a lubricant to the mix, making it "fatter" and more easily workable—so that a mix with less than the usual amount of water will flow quite as readily and be as easily handled on the shovel or trowel, or through a chute. The additional fatness and workability given by Cal produce a mix that reaches the bottom of the chute in the same uniform condition, with the same ratio of cement and aggregates throughout that it had when it left the top.

In this connection, it is important to note that Pearson and Hitchcock, after making an exhaustive test of workability came to the conclusion that hydrated lime in the form in which it is present in Cal is superior to ordinary dry hydrated lime in effecting workability of the mix and thus reducing the water ratio required.



Their conclusions are expressed as follows on Page 293 of the Technical Papers (Part II, Vol. 23, 1923) of the American Society for Testing Materials:

"Accelerator 'A' is a calcium oxychloride which quickly decomposes to calcium chloride and hydrated lime when mixed with water. The hydrated lime thus freed is much more effective upon workability, as indicated by the results of these tests, than the dry hydrated lime."*
**Cal.*

Reference again to the U. S. Bureau of Standards table quoted on Page 8, shows that with an 8% addition of Cal the water content for usual flow is about 2½% less than required for mixes to which no Cal has been added.

Aids in Frostproofing and in Densifying

FOR lowering the freezing point of the mix, and hastening its set so that it is exposed for a shorter period to the possibility of freezing, Cal will be found a valuable and dependable aid.

In general, Cal will render mortar or concrete proof against freezing at 10 degrees below the temperature at which the untreated mix could safely be used.

When concrete is placed at low temperatures, the most critical period of setting is during the first few hours immediately after the concrete is poured. After the setting action is well started, there is far less likelihood of damage. Cal is particularly effective at the earliest stages after the

concrete is poured in hastening the setting action of the cement. Also, because of its fatness and the consequent absence of "free water" in properly mixed Cal-Concrete, the possibility of freezing is still further reduced.

The use of Cal should not, of course, cause neglect of the well-recognized precautions for concreting in extreme weather, such as heating aggregates, heating water, covering finished work, etc.

The water-proofing characteristics of Cal are chiefly the result of the specially precipitated hydrated lime which forms an important part of the compound, and which in a less effective form has long been used independently for this purpose. The fatter mix obtained with Cal insures more compact and more complete filling of molds and forms, and closes up the pores of the concrete with very fine particles of hydrated lime. Its chemical action insures a thorough cure and the complete hydration of the cement through and through which is necessary for perfect and lasting impermeability.

Use of Cal to Correct Unsoundness in Cement

IN cases where the steam test shows an inferior quality of cement and where circumstances make it impossible, difficult or unduly costly to wait for a fresh shipment, the unsoundness can be corrected by the use of Cal. This has been amply demonstrated in actual field operations, and is authoritatively expressed as follows by the **U. S. Bureau** of Standards in Technologic Paper No. 174 **(Page 9):**

"A very unsound cement was used in a 1:3 mortar which was molded into 2-inch cubes and stored in air after 24 hours. At the end of 8 months, the plain mortar test pieces were entirely disintegrated. The test pieces made from the same mortar to which 5 per cent of undried Cal was added were still very firm, although a few disintegration cracks had developed."

Cement laboratory No.	Soundness after addition of various percentages of undried Cal			
	0 per cent	2 per cent	5 per cent	8 per cent
42895	Unsound; slightly warped, not hard.	Sound; very slightly warped.	Sound; very slightly warped.	Sound.
42896	do	Unsound; warped, hard.	Sound; very slightly warped, hard.	Sound; very slightly warped, hard.
43015	Unsound; very soft	Unsound; warped, not hard.	Sound	Sound.
43200	do	Sound	do	Do.
5	do		Sound; slightly warped, hard.	Do.

From Technologic Paper 174, U. S. Bureau of Standards.

The conclusion from these tests is expressed on page 22 of the above paper in these terms: "Unsound cements may be greatly benefitted or made sound by an addition of Cal."

Comparative Costs of Concrete Accelerators

IF one considers only the cost of the actual product required to produce a given degree of acceleration, commercial calcium chloride is, of course, cheapest. This chemical may be obtained in the granular or flake form, and is made into water solution before use. Its cost, when carefully used, is about 17 cents per barrel of cement treated, as compared with a cost of 60 cents for Cal, costs of $1.00 to $4.00 for the various "patent medicine" forms of Calcium Chloride, and about $4.50 per barrel more than Portland Cement for special quick hardening cements of the high alumina type.

For work where *acceleration only* is sought, and where the size and stationary character of the job permits the establishment of adequate equipment for the convenient storage and handling and the accurate proportioning and testing of the accelerator, calcium chloride will give satisfactory results at minimum cost.

In a large number of cases, however, the use of Cal, at the increased cost, will be justified. This is especially true where the concrete mixer is in motion (as in road and street work), where water connections have to be changed repeatedly, and where there can be no permanent provision for the preparation, storage, and analysis of the accelerator. On such jobs, the saving of time and the assurance of accurate proportioning alone warrant the extra cost.

In addition, however, it must be borne in mind that for the actual amount of calcium chloride contained in Cal, a higher degree of acceleration can be obtained because of the drier mix which Cal permits and the increased setting speed produced by this absence of the "free water" which retards hardening.

And, finally, where the *ultimate durability* of the concrete is given proper consideration, the increased fatness and improved cure of a mix obtained with Cal, will insure a permanence and quality which makes its increased cost a comparatively small item.

For the use of the "patent medicine" compounds discussed on the next page there is no real justification in *results* for the high costs fixed on these products.

In those exceptional cases where very high strengths are needed in 24 hours, it will often be found advisable to use special cements, but it is always necessary to compare costs with the actual saving in time which can be realized. Frequently it will be found that Cal and Portland cement will give all the strength necessary for the particular job in very little more time than the special cements.

Calcium Chloride in Disguised Forms

IT is a matter of common knowledge that herbs and chemicals of proved medicinal value and comparatively low cost are largely sold in compounds bearing a trade name at a tremendous increase in price.

The same thing has happened in the case of calcium chloride. Its acknowledged property of acceleration, and the protection this gives against freezing, has caused it to be used as the principal ingredient of a great variety of trade-marked products sold under names suggestive of these desirable accelerating and frost-proofing results.

Practically all these "patent medicine" products have one merit—the merit that results from the net amount of actual calcium chloride which they contain. But it will be found, upon chemical analysis, that this merit is the only one which they possess—and that other ingredients are added merely to disguise the base and to make plausible the tremendous increase in price over the cost of the calcium chloride. This increase runs anywhere from 300% to 1200%.

While Cal is also a compound with a base of Calcium Chloride its exact constituents have been made a matter of public record through the analysis of the U. S. Bureau of Standards, given in Technologic Paper No. 174 and its added advantage of convenience, safety, labor-saving, double acceleration, and improved durability in the resulting concrete give ample warrant for its higher cost as compared with ordinary calcium chloride.

[BLANK PAGE]

INTERNATIONAL

CCA

DEPARTMENT OF COMMERCE

TECHNOLOGIC PAPERS

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, Director

No. 174

EFFECTS OF CAL AS AN ACCELERATOR OF THE HARDENING OF PORTLAND CEMENT MIXTURES

BY

ROY N. YOUNG, Associate Chemical Engineer
Bureau of Standards

OCTOBER 11, 1920

PRICE, [illegible] CENTS
Sold only by the Superintendent of Documents, Government Printing Office
Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
[illegible]